DOCUMENT RESUME

ED 291 587 SE 048 919

AUTHOR Liske, Robert L.
TITLE High School Students as Collaborators in the Development of a Science Curriculum.
PUB DATE Apr 88
NOTE 29p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (61st, Lake of the Ozarks, MO, April 10-13, 1988).
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Curriculum Design; *Curriculum Development; *Curriculum Evaluation; *Curriculum Research; Formative Evaluation; *Instructional Development; Material Development; Physical Sciences; Science Curriculum; Science Education; Science Instruction; *Secondary School Science; *Student Participation; Students; Teacher Student Relationship
IDENTIFIERS *Science Education Research

ABSTRACT

In this study two high school students participated in the revision of a technology curriculum. These students were paid to work through lessons with one of the original authors to provide input for final editing and rewriting. The students were matched to the intended population for which the materials were originally written--poorly motivated students in high school. The two students had a high level of science anxiety as evidenced by their fear of science activities and tests. Findings indicate that students played a key role in identifying problems stemming from lack of clarity, both of directions and questions. Problems in the sequencing of materials were often noted by the students earlier than by the teacher or other authors. Additionally, students were helpful in the identification and correction of format problems, usually dealing with placement of pictures and charts in relationship to questions and comments. Perhaps the greatest contribution of the students involved the testing of the practicality of activities and experiments. The collaborative process between teachers and students in the development and revision of science curriculum materials tended to enable the development of higher quality materials that will require less revision at a later time. A 65-item bibliography is included. (Author/CW)

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HIGH SCHOOL STUDENTS AS COLLABORATORS IN THE DEVELOPMENT OF A SCIENCE CURRICULUM

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Robert L. Liske

Graduate Student
Michigan State University

SE 048 919

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ABSTRACT

HIGH SCHOOL STUDENTS AS COLLABORATORS IN THE DEVELOPMENT OF SCIENCE CURRICULUM.

Overview: Two high school students were invited to participate in the revision of a technology curriculum. These students were paid to work through lessons with one of the original authors to provide input for final editing and rewriting.

The students were matched to the intended population for which the materials were originally written - poorly motivated students in high school. The two students had a high level of science anxiety as evidenced by their fear of science activities and tests.

Findings indicate that students played a key role in identifying problems stemming from lack of clarity, both of directions and questions. Problems in the sequencing of materials were often noted by the students earlier than by the teacher or other authors. Additionally, students were helpful in the identification and correction of format problems, usually dealing with placement of pictures and charts in relationship to questions and comments.

Perhaps the greatest contribution of the students involved the testing of the practicality of activities and experiments. Some experiments did not work at all, some became workable as group rather than individual endeavors, and some activites even led the students to the wrong conclusion. Finally, students completing the activities gave a good sense of how much time was needed to comfortably complete each activity.

Students were helpful in indicating activities and materials that were interesting, and what activites actually helped them understand the material.

Conclusions: This collaborative materials revision project was valuable for the teacher-author in giving insight as to how students think - how situations are viewed, how pictures are interpreted, how phenomena are conceptualized, and how questions and directions are decoded.

The trial testing in local schools during the previous year indicated that teachers usually do not do experiments and activities ahead of time, and consequently had many problems with the materials. Activities and labs need to be developed to the point where they can stand on their own, able to be completed from the written instructions alone.

Writers and authors often already know the material so well that it is difficult for them to identify areas that are problematic to students.

The collaborative process gives teachers and authors insight into student perspectives, which in turn pinpoint problematic areas, not easily spotted. Many of the problematic areas arise due to preliminary assumptions as to students' pre-knowledge, conception of phenomena, and even simple understanding of terms.

The collaborative process between teachers and students in the development and revision of science curriculum materials enables the development of higher quality materials, that will require less revision at a later time.

Morever, developmental and testing costs are lower and information gained is more detailed when a writer works with two or three carefully selected students, than when several teachers engage in trial of the material in their classrooms.

HIGH SCHOOL STUDENTS AS COLLABORATORS IN THE DEVELOPMENT OF A SCIENCE CURRICULUM

Introduction - Purpose and Overview

The purpose of this paper is to report on a collaborative curriculum revision project, involving a teacher (one of the original authors of the curriculum being revised) and two high school students. Two technology units, entitled Wheels and Muscles and Bones, had been written during the course of the previous year, were introduced into three schools for trial testing and were now being revised for final printing. At this point, two high school students were selected and invited to participate in the curriculum revision, and were paid to work through lessons with one of the original authors to provide input for final editing and rewriting. This report is essentially a case study of this experience and the findings and conclusions that can be drawn from it.

In order to gain valid insight into the perceptions and preknowledge of these students, as well as to gauge the appropriateness of the content and activities of this group, the students used in the project were matched to the intended population for which the materials were originally written - the poorly motivated high school student.

Introduction - The Process of Curriculum Writing

The process of developing new curriculum has evolved over the last fifty years, both as to developmental process and end product. In the period of time prior to the 1950's, most school curriculum was based on an adopted textbook. These textbooks were usually written by one or perhaps two authors. In some cases, this was a scientist who knew much about science, but little about education or learning. Other textbooks were written by educators who knew a

great deal about learning, but had a marginal knowledge of science. Finally, some texts were written by learning theorists, who understood children, but had little idea as to what was really practical in the everyday classroom. For want of a better term, I shall call this "isolation curriculum development".

Measures to remedy the above developmental isolation were forthcoming in the late 1950's, when various curriculum groups were formed, using the "team approach" to develop new science curriculum. Writing teams now included educators, scientists, media specialists, artists, psychologists, and even practicing teachers. Two of the earliest products of these team efforts were the PSSC Physics program and the BSSC Biology program. After the initial draft was written, these programs were then sent out into the schools for trial testing, and the accumulated data was used for revision and final editing. However, in spite of over $500 million expended during the period of the 1950's and 1960's, little improvement in academic ability in science could be supported, especially for the average and low ability student.

The first level of development (isolation development) involved little collaboration, the second level (team approach) was characterized by collaboration among those already educated. The third level of curriculum development that I feel has many advantages is collaboration between educators and students - those being educated. This position is not to be exclusive. Recognition is given to the many positive approaches, in both team writing and trial testing, that were developed during the 1950's and 1960's, and can be incorporated into or used simultaneously with a teacher-student collaboration. This teacher-student collaboration is the focus of this paper.

HISTORICAL-THEORETICAL REFLECTIONS

The Problem

In spite of tremendous effort expended and immense financial resources allocated to American science education over the past three decades, it is still viewed "as deficient in purpose, scope, and style of teaching" (Hurd, 1986). As this problem is decomposed into various elements, it must be noted that America has some of the best schools, some good schools, many mediocre schools, and many very poor schools (Tamir, 1988). Furthermore, the problem of low achievement in science tends to characterize a segment of the high school population, rather than be representative of the entire educational system. Berkheimer & Maxwell (1986), in evaluating science education for the Michigan Science Teachers Association, concluded that the basic problem in not with the top 20% of our high school graduates who understand and remember. The real problem is with the other 80% who simply memorize and quickly forget. My own experience tends to substantiate a rising class of low achieving students in high school. When I first started teaching in a large suburban high school near Chicago in 1976, we offered one section of general (low-level, remedial) science. Five years later, we were offering three full sections of general science. Not only has the overall level of science achievement declined compared to other countries (A Nation at Risk, 1983), but the proportion of low-achieving students has increased, many of whom have at least average ability, but poor motivation to learn science.

Attempted Solutions

During the period from the late 1950's to the 1970's, the United States Government spent over $750 million in developing new science curricula and on implementation procedures. Three main thrusts characterized these developments - experiential science, individualized science, and modular/unified science.

On the experiential level, an attempt was made to bring the "process skills" into science classrooms, and give students firsthand concrete experiences with science objects. Discovery approach, inquiry learning, hands-on activities became the buzz words of the day. While some individual studies did show that discovery method can enhance thinking skills (Marek, 1973; Unan, 1979) and concrete experiences are beneficial for the low-achieving student (Schneider-Livingston, 1973; Okebukola, 1985), the overall pattern of science achievement did not improve and SAT scores continued to fall. Idar & Ganiel (1985) noted that superficial memorization of terms, knowledge of formulas, and some manipulation ability was "usually sufficient to mask the lack of understanding" (p. 129). Somehow the students were now "doing science", but still not really understanding (Roth, Anderson, & Smith, 1983; Smith & Anderson, 1984).

The second thrust was the development of specialized programs to meet the individual needs of every student. These took the forms of programmed instruction, audio-tutorial methods, computer assisted instruction, and comprehensive prepackaged science programs like the Intermediate Science Curriculum Study (ISCS). Again the results were not impressive, mixed to say the least. In most cases, programmed instruction, audio-tutorial, and computer assisted instruction were found to be no more effective than conventional instruction (Moore, 1973; Lehman, 1980; Staniskis, 1977). Individualized instruction was found to favor the higher ability students. (Tate & Burkman, 1981; Howe & Stanback, 1985). In all of these modes of instruction, the lower ability student was hampered by a low reading ability.

The third thrust was the development of modular/unified science programs. Some success with the low motivation student was claimed by the IASP project, described by Higgins (1973). However, the indicator of success was a lower

dropout rate and little evidence was given for increased academic achievement. In other programs, little evaluation was done, which makes it difficult to appraise the results. As one reflects on over twenty years of sustained attention to science instruction, many questions come to mind. What did we miss? Did we spend so much time on the methods, materials, and curricula that we neglected to understand the learner? Were global applications of principles invalid for a the great variety of students encountered? Were workable ideas and good programs simply not implemented on the local school level? Although each of these seem to partially account for the lack of impact of science curriculum on achievement, one in particular seems to have new significance. Recent research points to the importance of the perceptions, conceptions, and beliefs of the individual learner. Thus the remainder of this section will focus on the individual student as a consumer of science education.

Research Literature on Low Achievement

A literature review of over 200 research studies on the low-achieving science student revealed a wide variety of factors involved (Liske & O'Halloran, 1987). The variables could be classified as follows: cultural factors, home and community, student characteristics, and school factors (which includes teacher characteristics, teaching strategies, and curriculum). Each of these categories in turn contained many variables. For example, in the area of student factors, intelligence, reading level, math proficiency, and cognitive style indicate specific abilities, while self-concept, locus of control, and anxiety point to emotional and psychological factors. Even status factors like sex and whether a person is adopted correlated with achievement.

In the past, much energy has been spent agonizing over factors (such as SES level) that are to a large extent out of the control of educators. In order to make significant gains in educational achievement, it will be necessary to

analyze the variety of impinging causal factors, divide them into controllable and uncontrollable factors, and focus on those that are amenable to educational intervention.

The research on educational motivation shows a strong correlation between achievement and motivation (Srivastova 1977; Ugurogln & Walberg, 1979; Napier & Riley, 1985). An examination of the various definitions of motivation suggests a refocusing of attention on the individual aspects of achievement. Dweck & Elliot (1983) define motivation as the "contemporaneous factors that incite and direct behavior, that influence the direction, vigor, and persistence of an action" (p. 645). Maehr and Nicholls (1980) see motivation as goal directed behavior. Investigation into the motives of individual students may offer new insights to understanding low educational achievement and suggest profitable avenues toward higher achievement in science education

A Profile of the Low-Achieving, Low-motivated Student

If one were to attempt to create a profile of the low-achieving, low-motivated student, a number of factors are salient in much of the literature. First of all, low-achievement is not a distinction of only low ability students. Low achieving students range all the way from special education to very capable students, who for some reason neither care about or are interested in school . Often these students are very capable, but deficient in some specific area, that in turn hampers growth in other areas. Reading difficulty (Mayer, 1970; Srivastova, 1977; Rossock, 1982) and low math ability (Baker, 1985) are two of the more obvious deficiencies that contribute to low science achievement. Many of these students seem to have acquired misconceptions about science that can interfere with further understanding (Mentzes, 1984; Idar & Ganiel, 1985).

Probably more significant than specific subject matter deficits is the lack of metacognitive skills among low-achieving students. Dweck & Elliot's (1983) division of metacognitive skills into task analysis, strategy planning, and performance monitoring illustrate the range of skills involved. Cullen (1985) defines metacognition as "one's knowledge concerning one's own cognitive processes or products" (p. 267), and divides them into cognitive monitoring, strategic action, and coping responses. She indicates that achieving students are able to cope with ambiguity and error and many non-achieving students develop such anxiety and frustration that they exhibit "learned helplessness" (272). She asserts that impaired performance on the metacognitive level will interfere with cognitive functioning, even if there is not a deficit on the cognitive level itself. In describing negative coping she states that "in order to complete assignments, low achieving students developed strategies that contributed to task completion, but did not necessarily contribute to the mastery of the content or the acquisition or maintenance of adaptive learning to-learn skills" (290).

A third characteristic often found with the low-achieving, low-motivated students is a negative self-concept (Kramer & Walberg, 1981; Bradshaw, 1984; Handley, 1984). This low self-esteem takes various manifestations ranging from judgments of lack of competence, external locus of control, to negative self-attribution. Dweck & Elliot note that "achievement motivation may be viewed as involving goals related to competence - increases in competence and judgments of competence" (p.645).

Weisz and Cameron (1985) equate a person's view of self with what they call "self-efficacy", the ability to which that individual can influence outcomes and events. The amount of control over events or various situations is dependent upon two things; 1) contingency - the degree to which an event can be

controlled, and 2) competence - the individual's capacity to influence the events. Research has shown a strong correlation between what they call achievement and "locus of control". Low achievement is associated with external locus of control, meaning that these students feel what they personally do has little affect on the outcomes in their own lives (Burow, 1978; Rossock, 1982; Bradshaw, 1984; Sherris & Kahle, 1984).

Through a variety of previous experiences (performance accomplishments, verbal and social interactions, and evaluative cues), the student develops an expectation for either success or failure in regard to future events. McCombs (1986) asserts that in the face of failure, there is an "inherent need to establish and maintain a positive self-image and a sense of worth" (p.7). As a result, we find many students resorting to all kinds of adaptive and maladaptive actions to maintain a positive self-evaluation. One of the most common tendencies is for these students to adopt performance goals rather than learning goals. As explained by Dweck & Elliot (1983), performance goals are motivated by value judgments of peers, teachers, and parents, in which the student attempts to obtain a favorable judgment of competency and avoid an unfavorable judgment of inadequacy. Students with performance goals exhibit greater anxiety toward tasks, avoid challenges, and show less generalizability and transfer of learning. In contrast, children with learning goals, see the long term benefit of the task, and will complete the task for understanding and its own inherent value. Ames and Archer (1987) recognize the importance of this distinction in saying that "a performance goal orientation may actually provide a context that is not conducive to developing a positive achievement orientation and a longer term interest in learning" (p. 413).

Weiner (1985) sees these causal ascriptions as building blocks of motivational theory and gives three dimensions; locus of causality, stability,

and controllability. Locus of causality (Will the student's efforts make a difference?) contributes to feelings of self-esteem as pride. Controllability (Is the student responsible for the outcome?) contribute to feelings of shame, guilt, gratitude, and helplessness. Stability (Can a situation be changed?) contributes to feelings of hope or hopelessness. Weiner (1985) indicates that these beliefs about the causes of success and failure guide subsequent behavior. Various researchers are now finding that as students are taught to attribute success to controllable causes (like effort) and are simultaneously taught specific strategies for coping with task, motivation to learn can be increased" (Cullen, 1985; Reid & Borkowski, 1987).

As previously indicated, students' self-perception and emotions have a long--term affect on learning. For instance, a high level of anxiety is directly related to low science achievement (Dhaliwal & Saini, 1975; Gabel, 1983; Trout & Crawley, 1985; Napier & Riley, 1985). Cullen (1985) asserts that the anxiety, frustration, and anger about school often develops as early as eight years of age, and the continuing negative affect of these emotions continue to interfere with the child's effective use of metacognitive strategies.

The profile of the low-achieving student then is one of unclear, or maladaptive goals, low self-esteem, external locus of control, weak metacognitive skills, and in some cases weak cognitive skills. Repeated failure has ingrained a low expectancy for success, and causal attribution to uncontrollable factors.

Granted that many of the preceding factors are beyond the control of the educational system, the concern of educators needs to be directed toward those aspects of learning amenable to treatment. It would seem that a special target of intervention should be the child of average or above average ability who is underachieving. The task of the teacher then becomes one of understanding the

beliefs, attitudes, values, and circumstances that bring a child to this nonproductive point in life. The focus in the next section will be on understanding this student perspective.

The Student Perspective

After years of developing curriculum in isolation from students, researchers are beginning to understand the utility of the student perspective. Cullen and Carver (1982) elicited from students what they considered to be inappropriate teaching practices. The ability of students to identify methodology that either made it difficult for them to learn (like omitting examples to illustrate an idea) or discouraging aspects of relationships and structure (like the teacher's response to failure) was enlightening. Schunk (1987) indicates that self-efficacy is related to "student's beliefs concerning their capabilities to organize and implement actions necessary to attain designated levels of performance" (8). The level of self-efficacy will influence the student's choice of activity, the effort expended, and the persistence on task. Dweck and Elliot (1983) postulate that the beliefs of students have a direct impact on motivation, especially in regard to choosing either performance goals or learning goals. If the preceding is true, then how could we as educators develop curriculum and instruction and neglect to consider the beliefs and perspectives of the students for whom it was intended? The following will consider the importance of what a student believes about himself, about the school, the learning environment, and about the material called curriculum that will be foisted upon him/her.

The structure of the school, the attitudes and beliefs of the teacher, and even the curriculum will help fashion what a student believes about himself. Some of the characteristics of the new curricula for low-achieving students grew out of an attempt to program success into the materials. However,

Dweck (1986) points out that "frequent praise and short easy tasks do not create a desire for long challenging tasks" (p.1046), but may even reaffirm a sense of "being dumb" and contribute to a further decline in performance. She continues to say that "a failure to teach the necessary high-level skills . . . account for much of the achievement deficit of low reading groups" (1046).

The very fact that a teacher is willing to hear the opinions and value the insights of a student can contribute to a sense of control. Are the strategies being used by the teacher allowing the student to cope with the task? Are some elements in the explanation missing, thus causing confusion? What part of the task is frustrating to the student? What activities or materials are offending to the point of even being considered "sissy stuff"? What part of the directions are not clear? What are the steps necessary to even get started with a project? Involving the students in activity evaluation and planning, in contrast to individual assessment, helps build a sense of ownership in the endeavor and empowerment to the individual.

A number of research studies indicate that low-achieving students see little relevance between the material taught in their classes and their own lives and (Kalra, 1973; Kolb, 1967; Simpson, 1982; Pope & Gilbert, 1983). Furthermore, little of the material is projected to have value for their own futures (Smith, 1977; Yager & Pinick, 1983). Ponder these questions. Who knows better what and how the material is relevant to the lives of students than the students themselves? Who might be able to create situations of relevance that communicate to other students better than students themselves? Instead of using students to help create situations that communicate in a clear and relevant fashion, we have constructed an evaluative, performance atmosphere, that often pits teachers against students, students against students, and students against teachers. In this face saving game, Johnson &

Johnson (1985) present evidence that "in the generally competitive climate of most schools, success at academic tasks has little to value for many students and may even be a deterrent to popularity with peers" (p. 258).

Communication with students by teachers goes beyond the verbal level. Teacher beliefs and expectations about a student are often inadvertently communicated to students in an indirect manner. Good & Tom (1985) state that "teachers can and do make an important difference in influencing motivation through the way in which they model and react to student success and failure" (p. 318). One aspect of teacher beliefs about students that is now recognized as significant are teacher expectations. At least nine of the studies in our literature review show a correlation between achievement and teacher expectations. These expectations impact students in direct and indirect manners, ranging from ignoring low-achievers (McDermott, 1979), to underestimating their ability (Harris, Findley, and Good, 1982). Brophy (1985) states that "expectations do not affect students directly, but they lead to modeling, direct instruction or socialization, indirect communication through questions, spontaneous reactions, expressive affect, and these behaviors do affect students" (185). He goes on to show how negative teacher reactions toward low-achieving students actually become self-fulfilling prophecies.

It thus becomes imperative for teachers to recognize that students do have valuable input that can be used in the construction of a learning environment. The beliefs, attitudes, insights, and interests of the students are important in learning and must be considered by teachers. The willingness to share planning and evaluation with students contributes to their sense of self-esteem. Above all, the expectations of the teachers must be such that communicates a message of "I believe in you!".

The Implications

Returning once more to the purpose of our project, developing curriculum for the low-achieving, low-motivated student, we ask, "What are the implications of the preceding research for our particular project?" How can the insights and perceptions of students be used to help create a curriculum that commands the respect of students, will be relevant to their lives, develop competence, and be valuable to their continuing education?

Researchers are beginning to realize that building a learning environment is a shared project, in which collaborative goal setting, strategy planning, and work evaluation contribute to feelings of competence, respect, and a perception of personal control. Kershaw and Scott (1975) developed a curriculum in which students and teachers worked cooperatively to choose topics for study. Even though scant evaluation limits the inferences that can be drawn from this project, other studies indicate the importance of student involvement in learning (Woolnough, 1975; Staniskis, 1977; Spraggins, 1984). A motivational learning environment will be one which facilitates an internal locus of control, enhances competence, provides choice or autonomy, provides challenge and interest, gives immediate and informational feedback, and offers social setting in which academic activities are valued (Ryan, Connell, & Deci, 1985). Cullen (1985) describes a motivational learning environment as one where the focus is on problem solving rather than evaluation, where competition is de-emphasized, where social comparison is discouraged, where ambiguity and error is accepted, and an increasing amount of responsibility is placed on the student.

If the beliefs of students do have a great impact on motivation, and motivation is a large part of their achievement, at what level can their involvement be solicited - at the curriculum development level, at trial

testing, at rewriting, implementation of new curricula, or during instruction? My personal belief is that increased student involvement in the planning and evaluation of learning needs to be increased at all levels. Dweck's (1975) attributional training model for increasing motivation suggests ways students could be involved. She suggests developing coping dialogues for attributing failure to controllable causes, placing an emphasis on strategic effort and development of strategic maneuvers to approach problem solving, and development of procedures to use errors constructively.

A final note! Collaborative development is a cooperative process in which teachers, students, and curriculum developers work together, sharing ideas, trial testing procedures, generating possibilities, evaluating products, and above all sharing concerns that help make education meaningful and successful. There is no suggestion that decision making is to be turned over entirely to students. In fact, Long et al (1981) claim that low-ability students do better with teacher-managed instruction than with student-managed instruction. Teachers and developers play a critical role in organizing the learning process, and in providing leadership. The students play a critical role in furnishing the input that makes the material relevant, workable, and interesting.

REVISING CURRICULUM WITH STUDENT COLLABORATORS

Project History

During late 1985, Michigan State University in conjunction with three Michigan school districts, forwarded a proposal to the Michigan Department of Education for funding to develop science curriculum for the low-motivated, low-achieving students in high school. The funding was granted, and during the course of the 1985-86 school year six teachers (two from each school district), two graduate students in science education, and Dr. James Gallagher from Michigan State University worked as a team to write the first draft of two technology units, entitled Wheels and Muscles and Bones.

These units were then trial tested in two participating school districts, and input from these experiences were used in the revision process. However, the feedback information proved to be very sketchy, in most cases general comments like, "This didn't work" or "That was too hard". Little indication was given as to why students were having difficulty, or how the students perceived the concepts, instructions, diagrams, or questions. A meeting of the original writing staff in the spring of 1987 ended up in a debate as to what content should be included, and what was to be deleted.

A series of classroom observations illuminated another problem with the field testing program - wide scale adaptation of the original units as written. Some teachers used only parts of the program, others added material of their own, and still others used this activity based program in a textbook mode of teaching. Consequently, little of the feedback information was relevant to the original text being revised.

During the time the units were being trial tested in the schools, a second proposal was forwarded to the State of Michigan requesting funds for revision, final editing, and printing. This proposal was funded, but only at a portion

of the requested level. This eliminated the possibility of hiring back the six teachers to work over the summer. Subsequently, two graduate students were hired to complete the task of revising these technology units. Two factors initiated the idea of using students in the revision process - the frustration of having been assigned a task without adequate information to complete this task, and a prior experience of having successfully used students in the original writing of science curriculum.

The Students Selected

The students invited to participate in this curriculum revision had a history of difficulty in school, both on the academic and social level. Nancy, now a junior in high school, had difficulty reading in junior high, being at least two grade equivalents behind, as tested by the California Achievement Test. Her dislike of school was so intense, that academic difficulties began to translate into physical problems, and a high level of absenteeism resulted. Ernie, now a high school sophomore, also disliked school, had been in two different high schools, and then dropped out of school. At the time of contact, both students were not enrolled in a formal school, being educated at home by their parents, and so were available to spend considerable time working on this collaborative project.

The Role of the Students

The success of a collaborative teacher-student curriculum revision depends, to a large degree, on the roles established at the beginning of the project, and the sense of credibility that can be established. This type of student is not accustomed to having adults seriously value their opinions. Thus a good portion of the first session with the students was spent explaining that their opinion was needed. They were to work through the materials, just as if they were in school, attempting to complete as much as possible from the written

text. For this part they would receive credit for the work completed through a local high school. In addition, each student would be paid $50.00/project for their assistance in locating errors, noting sections of text they did not understand, and identifying text and experimental directions that were confusing or incomplete. After some initial skepticism, these two students enthusiastically accepted the role of being able to correct and evaluate the work of teachers.

The Contribution of Students to Curriculum Revision

The input of the students proved valuable in a number of ways, ranging from simple editing, clarification of directions, sequencing problems, to the identification of student conceptions of phenomena that differed from the writers, and testing the practicality of activities.

It was amazing how quickly these two students took the task of revision seriously. It almost became a game for them to find spelling errors, typing mistakes, and in some cases grammatical errors. Although this level of editing could easily have been performed by an experienced adult, it served to initiate the students into their role.

Another contribution of these students developed out of the free interactive process between the students and the teacher-observer. Lack of clarity in the materials was quickly indicated by simple comments as "I don't understand" or "I don't get it". Sometimes the response of students was simply a lack of action accompanied by a blank expression. These incidents contributed to clarification of directions for activities and experiments, as well as clarification of questions in the written text.

A third type of contribution had to do with sequencing problems. In some cases, information to answer a question was given after the question. In other cases, questions were posed and the students were unable to find the answer in

the written text or draw upon their previous knowledge to answer the question. Finally, critical pieces of information were missing, and the students were stymied in their ability to generate an answer or understand the text.

It was interesting, as an author, to find that one of the most common hindrances to students understanding the written text had to do with simple format problems. In one case a question depended on a diagram following the question. During the course of the final typing, the page break occurred between the text and the diagram, placing the diagram on the next page. When the two students came to this part of the text, they were unable to proceed until I realized what had happened, and asked them to turn the page. In another case the position of two pictures were interchanged during final paste-up. This caused great confusion to the students, but was not noticed in the previous editing. Another format problem quickly noticed by students was incorrect page numbers (ones referring to another portion of the text). These are usually generated while revising text if a repagination occurs using a word processor.

A fourth type of input valuable to revision had to do with the students' perceptions. For instance, the purpose of one lesson was to develop a model for solving problems. This was intended to be a set of procedures, an accumulation of necessary information, a plan to help an individual arrive at a logical decision. Brief conversation with the students quickly revealed that their idea of a model was a small scale rendition of a larger object, like an airplane model. Once this understanding had been clarified, the lesson progressed nicely. Another unexpected perception difficulty had to do with the interpretation of pictures. In one exercise the students were to identify the safety features that represented technological design in a car. The picture of a seat belt was to be matched with the response "warning buzzer". However,

this was not the response generated in the minds of these two students when they looked at this picture. Another misconception had to do with the word "laminated." Both students believed that laminated means "coated" and consequently the direction to make a lamination with three layers was confusing to them.

Perhaps one of the most valuable contributions of the student collaborators was in testing out the practicality of activities and experiments. Some activities, even those logically devised, simply did not work. One of these was a lamination that was to be made using plastic wrap and aluminum foil. With both being relatively impervious to moisture, the glue never dried. Some activities can lead to an unintended and wrong conclusion. In one activity, the author had students graph the horsepower of automobile engines against the miles per gallon. A chart was taken directly from a MotorTrend Magazine and assumed to give the correct results. When plotted by the students, Ernie's conclusion was "The bigger the motor, the better the gas mileage." I immediately checked the accuracy of his graphing techniques, and had to agree that this is what the graph indicated. It just so happened that an interesting mix of various sized cars, both foreign and domestic, produced the odd result. Student completion of activities was also very helpful in unit planning, especially in assigning projected time needed for various experiments and activities. Finally, some activities proved to be workable in a different mode of learning. For instance, the students were to fill in a chart matching various components to specific subsystems in the automobile. For Ernie, this task was easy, but Nancy was unable to start. I suggested they work on this as a team, which enabled them to easily complete the chart. In the teacher's edition, this activity was then changed from an individual activity to a group activity.

The last valuable input received from students was their subjective input regarding the materials. Interesting portions were nicely pointed out with comments like "That's neat!" and, conversely, dull portions elicited a response like "That's dumb!" Another aspect where students were helpful to the editor was by indicating portions of greatest utility to the learning process. "That really helps me understand" in opposition to "I don't get it" were key flags to probe further and make special notes by the researcher.

Conclusions

1. A collaborative revision project can be of great value to a teacher to increase understanding of how students think. Insights are gained as to how students view situations, explain phenomena, interpret pictures, decode questions and analyze directions.
2. One of the problems with authors editing their own work (being so familiar with the subject matter, pictures, etc.) is that they are unable to spot areas that will cause difficulty to students later on. Students quickly spotted these types of errors.
3. The field observations verified that teachers seldom trial run activities or try out labs ahead of class time. Consequently, the lessons in a curriculum must be written to stand on their own, meaning that the teachers can make preparations and the students can follow directions from the written instructions alone.
4. The collaborative process gives teachers and authors insight into student perspectives, which in turn are invaluable in pinpointing problematic areas that need revising. Many of these problematic areas arise due to preliminary assumptions as to students' preknowledge, students' explanations of phenomena, or even simple understanding of concepts.

5. One of the greatest benefits of the collaborative approach is financial. The total cost for one planning session, to which five teachers were invited as consultants, amounted to $250.00. The cost for meeting with two students, three hours a day, for a period of twenty days, amounted to $100. The input from the students was by far greater, more relevant, and much more valuable than that received from the teachers in one meeting.

6. Considering all the previous observations and conclusions, I believe the collaborative process between teachers and students in the development and revision of curriculum enables the development of higher quality materials that will require less revision at a later time.

Final Note

In that the procedures for this project were developed during the course of the project, as a response to necessity, this paper does not purport to be the culmination of a research project, testing an educational hypothesis. However, the research literature does point to the utility of involving students in the development and revision of curriculum. As can be noted in the section entitled "Historical-Theoretical Reflections", a theoretical basis is available to substantiate the validity of this approach. Further testing, on a more formal basis, especially in the area of original curriculum development is needed.

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